Managing Urban Garden Soils to Minimize Potential Soil Contaminant Transfer to Humans

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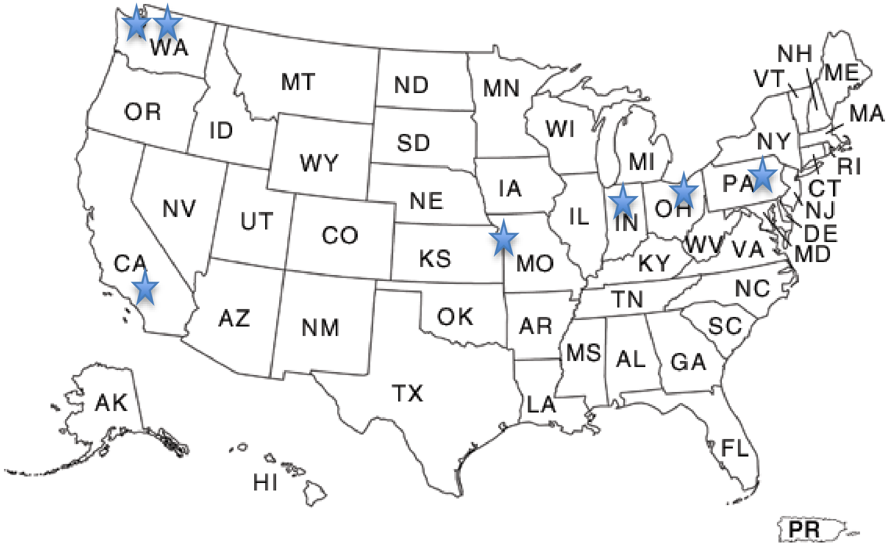
Contaminants in Urban Soil

lead (Pb) from paint and leaded gasoline; arsenic (As) from pesticides or naturally occurring; polycyclic aromatic hydrocarbons (PAH) from incomplete burning of C-containing materials; DDT, and chlordane as pesticides

Project: Gardening Initiatives at Brownfields sites

7 test sites across the USA: Kansas City, MO; Tacoma, WA, Seattle, WA; Indianapolis, IN; Pomona, CA; Philadelphia, PA; Toledo, OH



Funded by the EPA Brownfields Training, Research, and Technical Assistance Grants Program

Example Site 1: Kansas city, MO

Size ~ 42m x 37m

Silt loam (Sand-4%, Silt-75%, Clay-21%)

The site was screened *in situ*, every ~6 m for trace elements using x-ray fluorescence spectrometer

↓

Moderately elevated Pb

Soils were also tested for chlordane

Attanayake et al., 2014. J. Environ. Qual., Vol. 43 No. 2, p. 475-487

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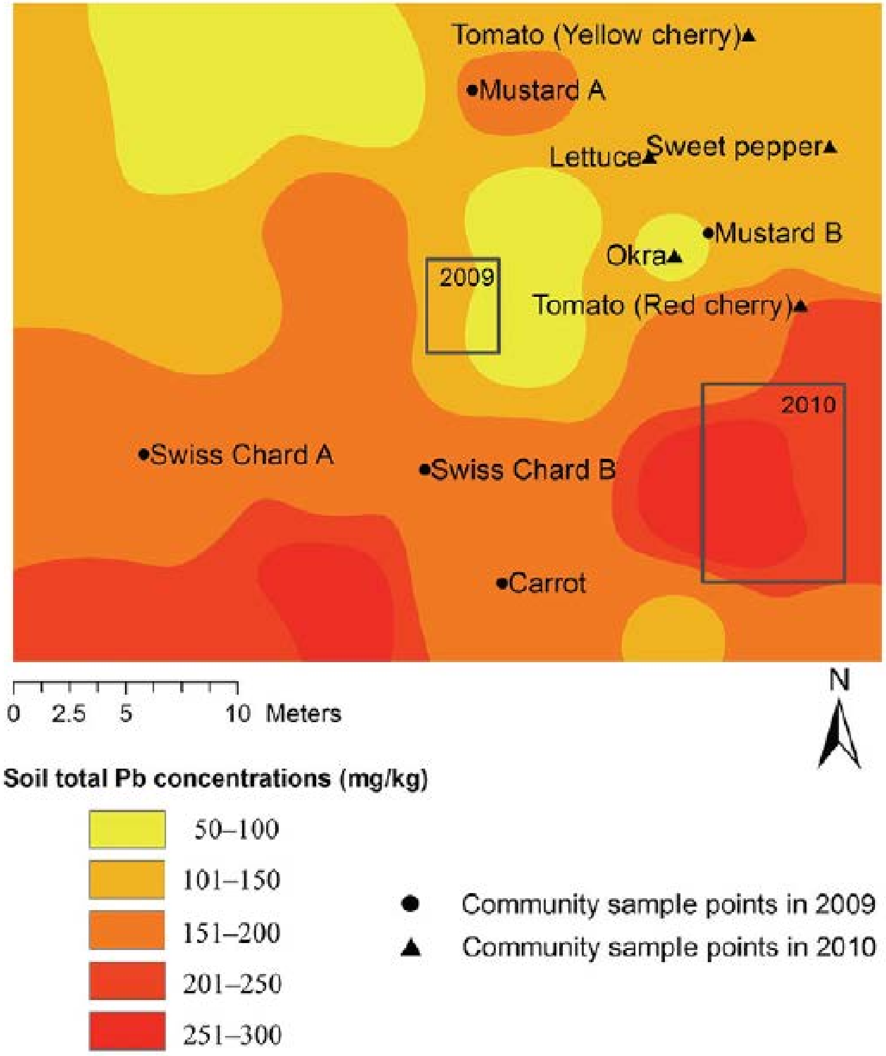

Distribution of soil total Pb concentrations

**Laboratory conformation analysis-Using EPA 3051 method

Chlordane - n.d.
DDT- 0.04 mg/kg to1.3 mg/kg
DDE - only detected in two of the submitted samples (0.03, 0.04 mg/kg)

Selected Soil Properties

Sample ID	pH	Mehlich-3 P	Ext. K	NH_4-N	NO_3-N	OM
		---------------------- mg/kg			----------------------	%
9S	6.6	130	624	53.6	73.2	3.9
9D	6.6	93	455	9.6	35.1	3.4
21S	7.2	116	417	11.8	22.7	3.0
21D	7.2	123	221	9.3	15.0	3.1
26S	7.8	57	255	8.3	4.3	1.5
26D	7.6	80	260	8.2	2.2	1.1
39S	6.9	154	488	15.0	24.2	4.7
39D	6.9	149	334	9.6	13.3	3.3

S = 0-15 cm
D = 15-30 cm

Texture: Silt loam with 21% clay

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Test plot-2010

April 2010.

<u>Treatments</u>:

No compost and compost @28 kg/m^2

<u>Crops</u>:

Swiss Chard

Carrots

Tomato

June 2010.

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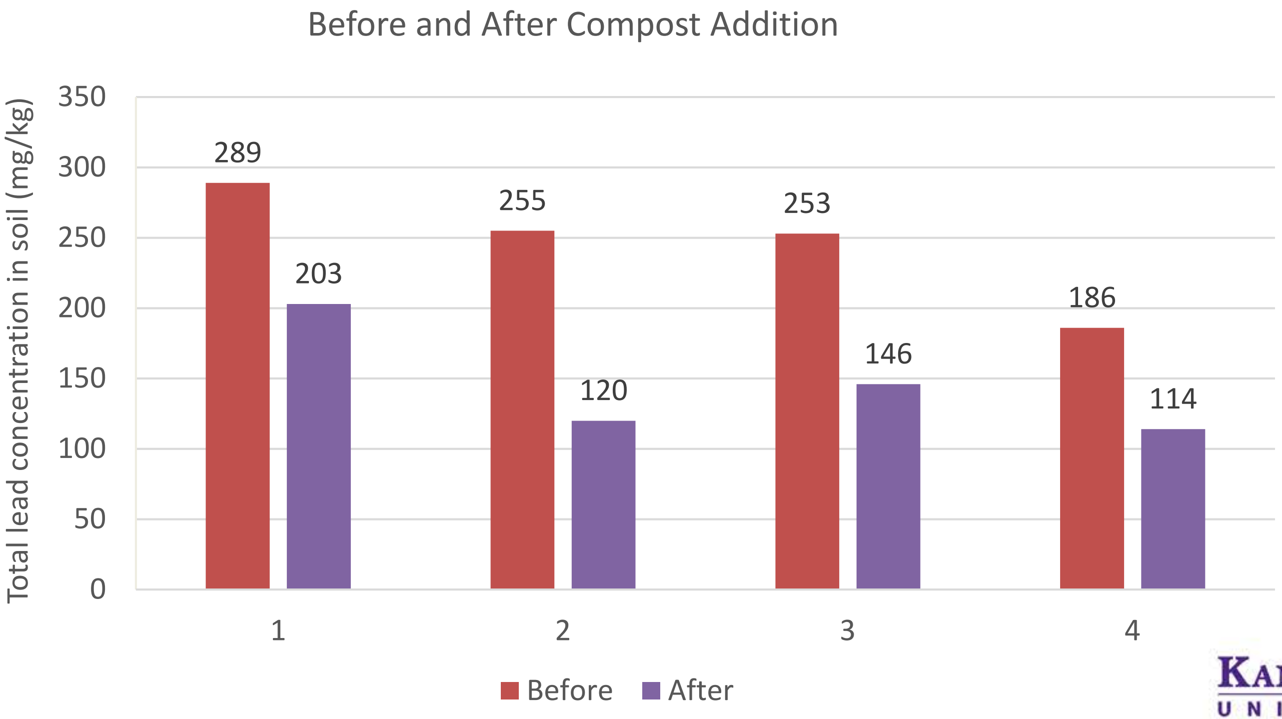
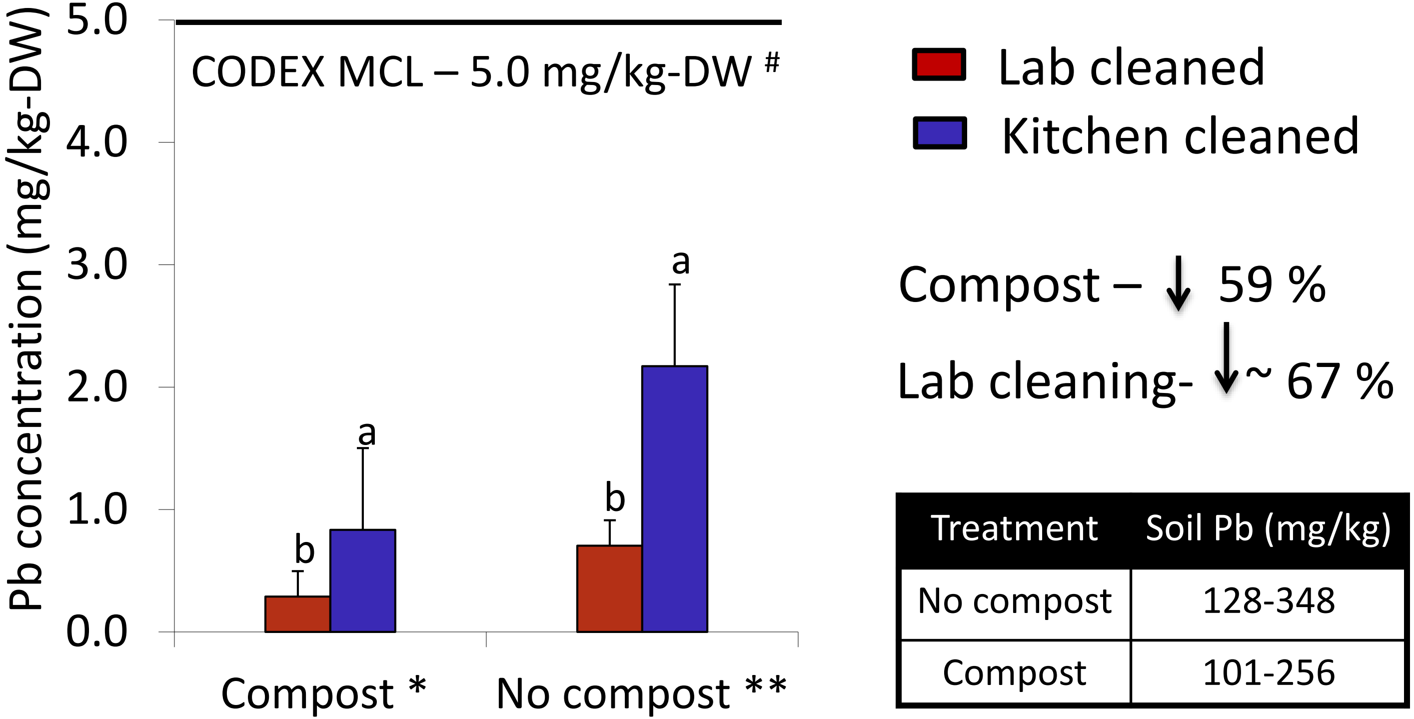
Dilution effect on total contaminant concentration in soils

Kansas City, MO



Lead Concentration in Swiss Chard



Compost – ↓ 59 %

Lab cleaning- ↓~ 67 %

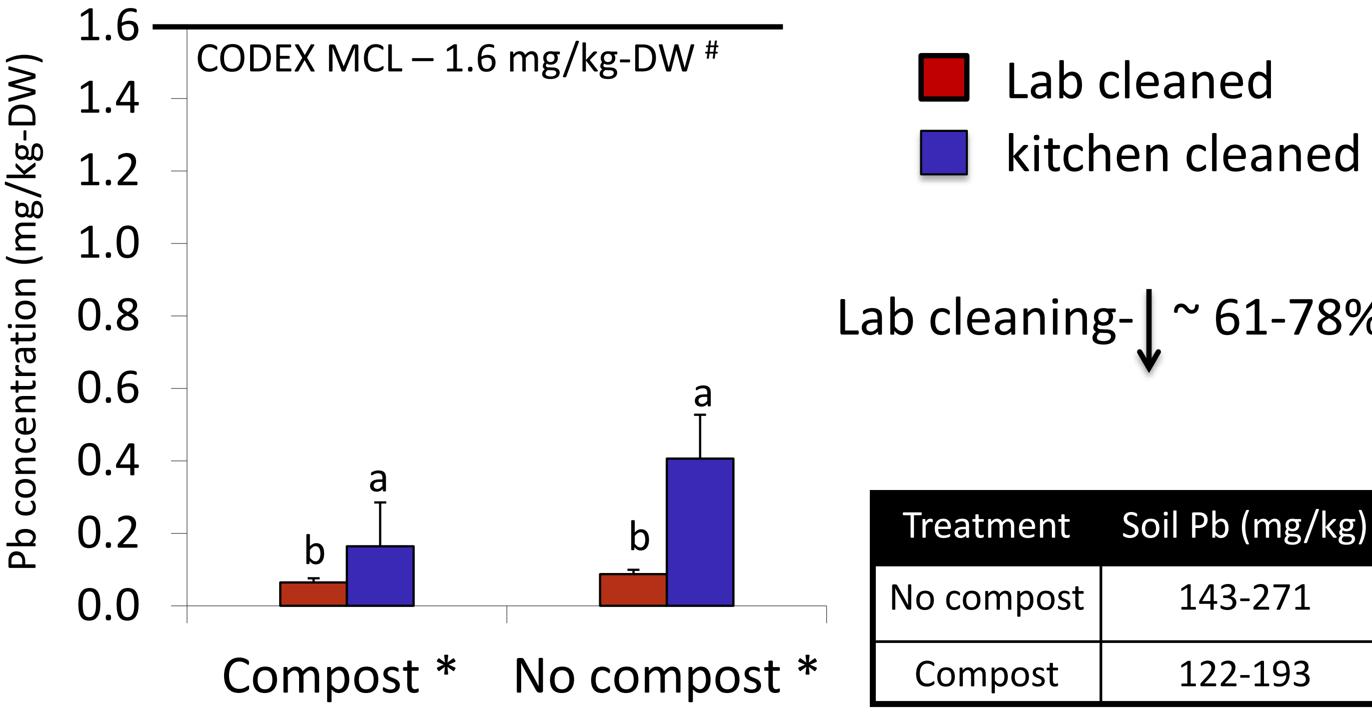
Treatment	Soil Pb (mg/kg)
No compost	128-348
Compost	101-256

$p<0.05$ (split plot design, 4 blocks)

*,** between two categories a, b- within a category

CODEX MCL (FAO/WHO) - 0.3 mg/kg fresh wt. basis (94% moisture)

Lead Concentration in Tomato



Lab cleaning-↓ ~ 61-78%

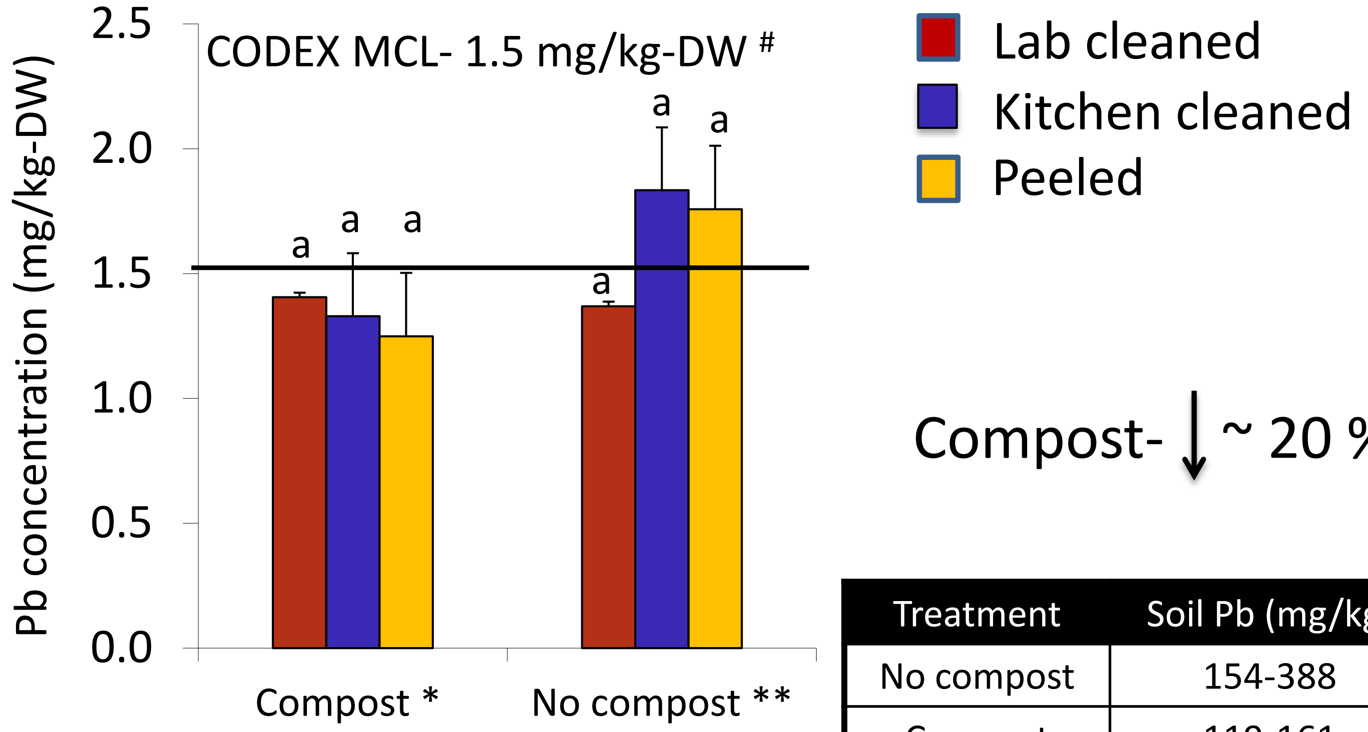
Treatment	Soil Pb (mg/kg)
No compost	143-271
Compost	122-193

$p<0.05$ (split plot design, 4 blocks)

*,** between two categories a, b- within a category

CODEX (FAO, WHO) - 0.1 mg/kg fresh wt. (94% moisture)

Lead Concentration in Carrot



Compost- ↓ ~ 20 %

Treatment	Soil Pb (mg/kg)
No compost	154-388
Compost	119-161

p<0.05 (split plot design, 4 blocks)

*,** between two categories a, b- within a category

CODEX (FAO, WHO) - 0.1 mg/kg fresh wt. (93% moisture)

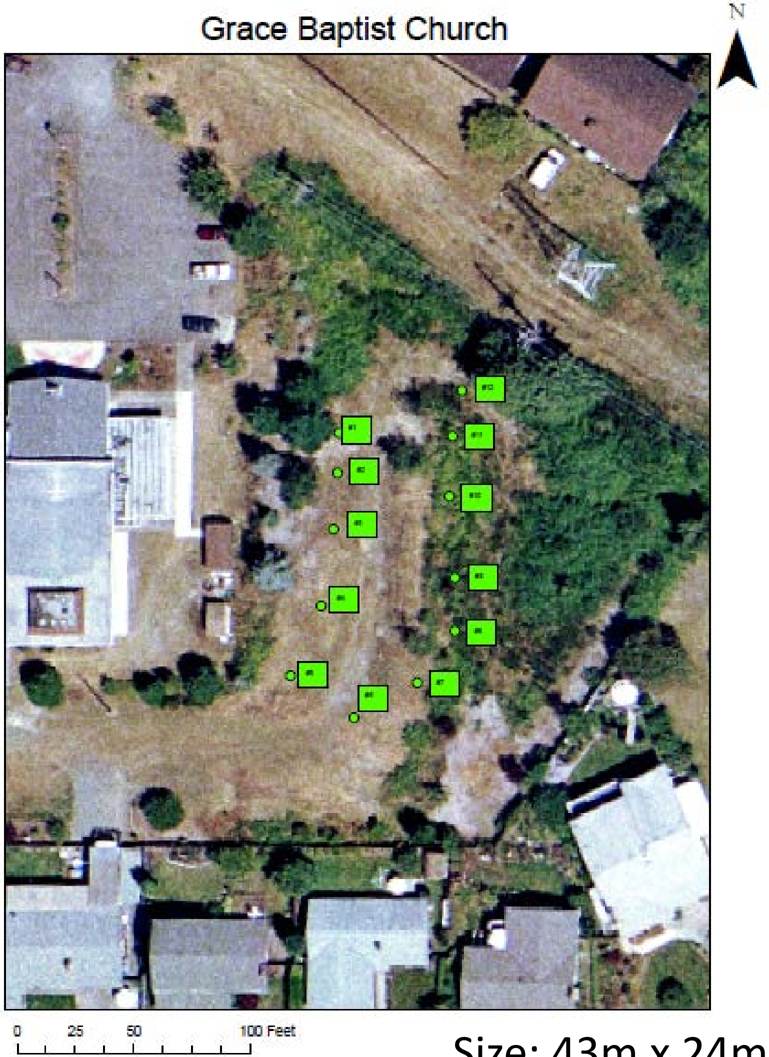
Example Site 2
Tacoma, WA

Element	Concentration in soil (mg/kg)
As	17- 162
Pb	17- 427

Texture: Sandy loam

Soil pH: 5.6 (soil: water)

Ref.: Defoe P.P., G.M. Hettiarachchi, C. Benedict, S. Martin. 2014. J. Environ. Qual. doi:10.2134/jeq2014.03.0099



Size: 43m x 24m

Test plots-Tacoma, WA- 2010

Low to medium available N, P and K in soils

Treatments:

No compost and compost @ ~28 kg/m^2

Crops:

Lettuce, Carrots

Tomato

Tacoma, WA- Test plots

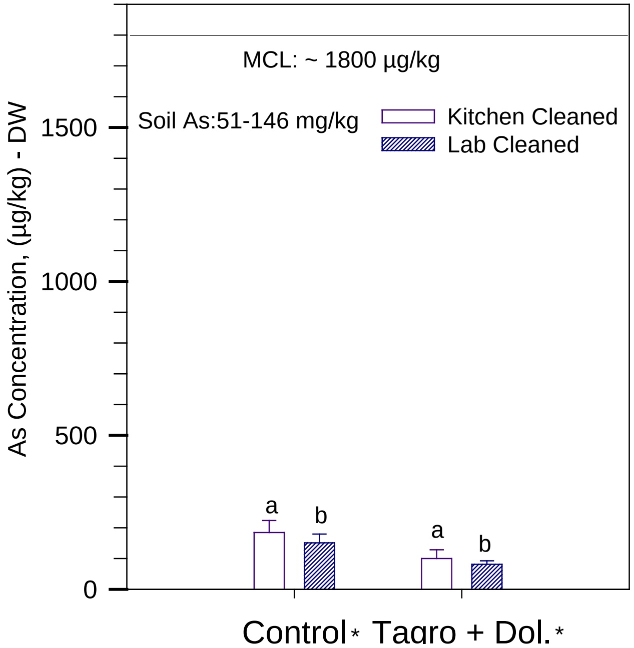
Dolomite+Tagro added

Control

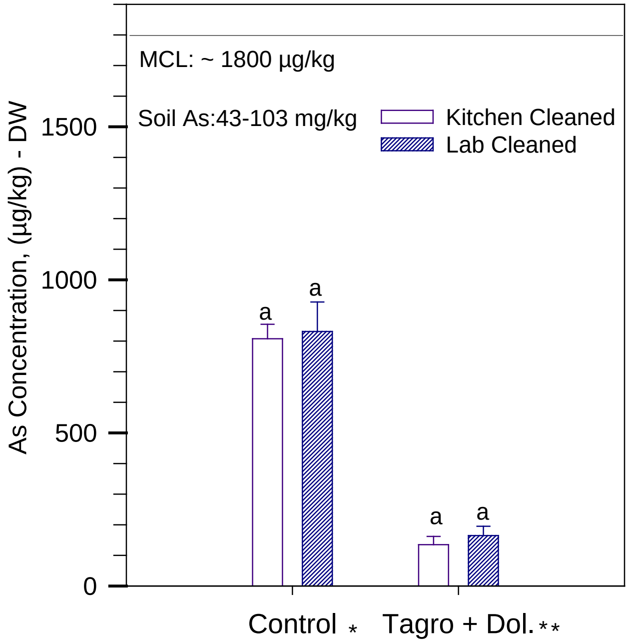
Further dilution of contaminants in plants through enhanced growth

Lead uptake patterns by tested vegetable types were similar

Arsenic in Lettuce



2010

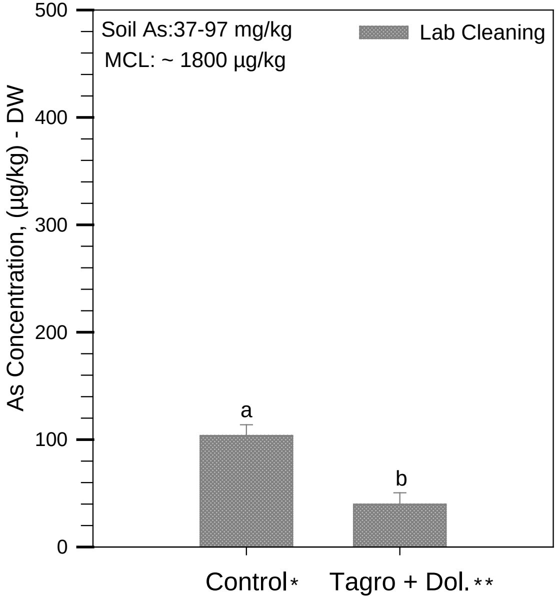


2011

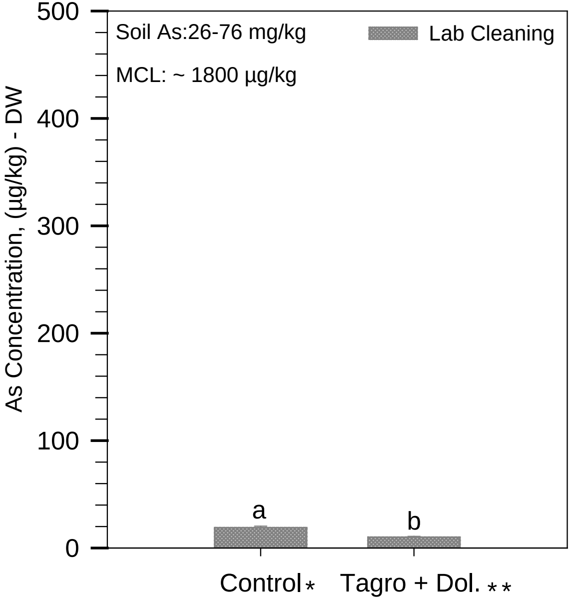
Vertical bars represents the means of four replicates

* MCL- Estimated using oral exposure daily reference dose limit for inorganic As

Arsenic in Tomatoes



2010



2011

Vertical bars represents the means of four replicates

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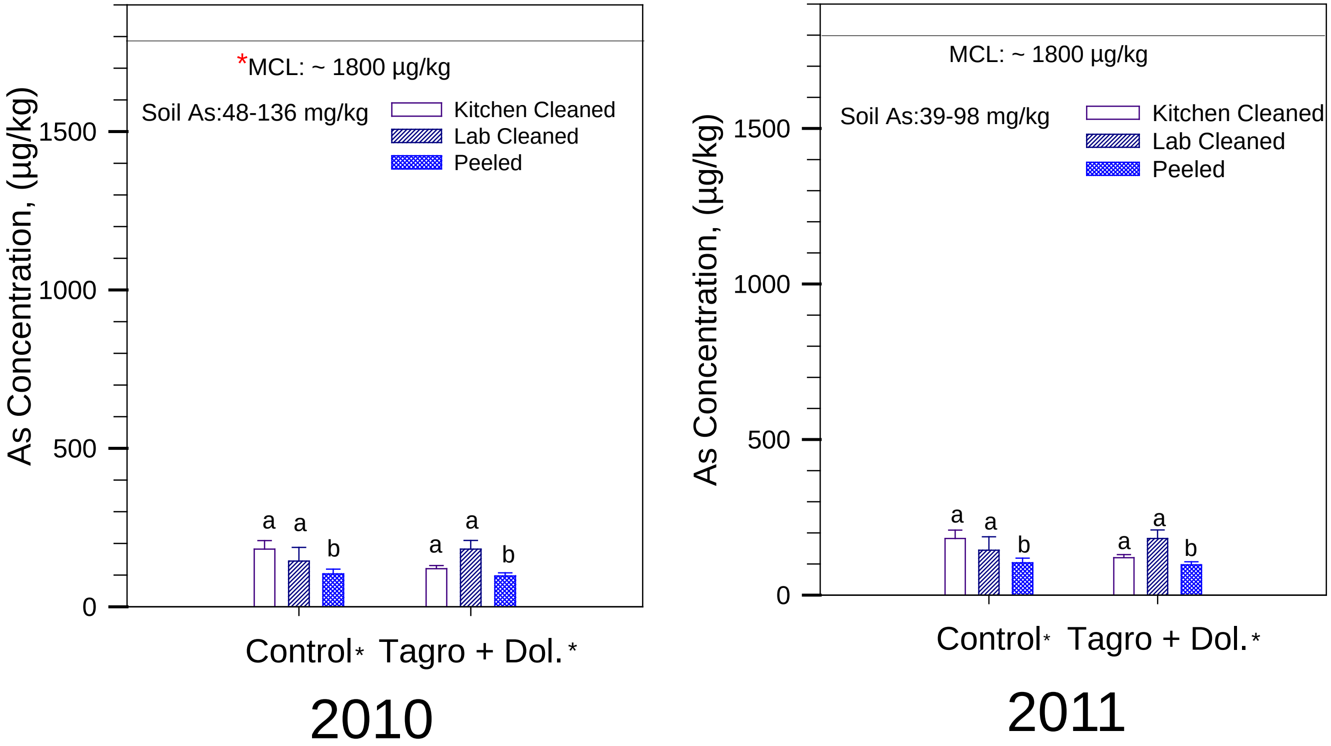
Arsenic in Carrots



Vertical bars represents the means of four replicates

* MCL- Estimated using daily reference dose limit

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Physiologically Based Extraction Test-PBET Results

Testing gastrointestinal dissolution of soil As and Pb At pH= 2.5

Treatment	PBET As†	Soil As	Bioaccessible As (% of total As)	PBET Pb	Soil Pb	Bioaccessible Pb (% of total Pb)
	--------mg/kg-------			------mg/kg-----		
Control	5.5	81.9	6.9	23.8	171.5	14.2
Tagro + Dolomite	5.1	77.6	6.6	19.2	192.8	9.2

†Analysis performed on AA240Z GF-AAS (Australia) with Zeeman background correction

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Example site 3: Monon Acres- Indianapolis, IN

Inorganic contaminants

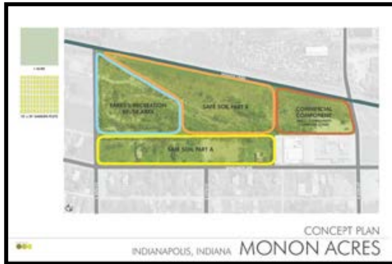
- Screen for inorganic contaminants using XRF and lab confirmation

	Lead	**Arsenic**	Cadmium	Chromium	Copper	Zinc
	mg/kg (ppm)					
Site soil	**437-513**	**23-84**	2-16	69-81	229-308	576-2486
Limit ‡	150 400†	20	20	1500	750	1400

‡ Max. concentration allowed Agricultural soils treated with sewage sludge (McGrath et al., 1995)
† Residential soils, Children's play areas (EPA)

Organic contaminants

Site history, located near the former Monon railroad and railroad maintenance station → **∑ Polycyclic aromatic hydrocarbons (PAHs)**: max. 50 ppm



Test plots- Indianapolis

May 2011

July 2011

Amendments (4 compost types): Leafy compost, mushroom compost, composted biosolids, non-composted biosolids

PAHs in Soils and Vegetables- 2011

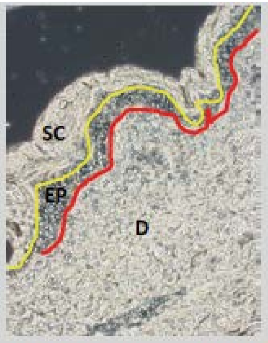
Toxicity

# of rings	PAH	Range in test plots (ppm)	Tomato and Carrot (ppm)
2	Naphthalene	<0.4-1.4	< 0.01
3	Acenaphthylene	<0.4-2.4	< 0.01
3	Acenaphthene	<0.4-0.8	< 0.01
3	Fluorene	<0.4-0.8	< 0.01
3	Phenanthrene	6.8-5.6	< 0.01
3	Anthracene	0.5-4.5	< 0.01
4	Fluoranthene	1.6-1.4	< 0.01
4	Pyrene	1.5-1.2	< 0.01
4	Chrysene	1.4-10.4	< 0.01
4	Benzo (a) anthracene	1.1-8.2	< 0.01
5	Benzo(b)fluoranthene	2.6-18.7	< 0.04
5	Benzo(k)fluoranthene	<0.4-6.0	< 0.04
6	Indeno(1,2,3-cd)pyrene	1.1-6.8	< 0.04
6	Benzo(g,h,i)perylene	<2.2-7.2	< 0.04
5	Benzo(a)pyrene	1.4-9.9	< 0.10
5	Dibenz(a,h)anthracene	<0.4-2.3	< 0.10

Attanayake et al., 2015. Journal of Environ. Qual. 44:930-944.

Dermal transfer- PAHs

- In the context of gardening, it can be hypothesized that dermal absorption (skin contact with contaminated soil) could be a significant pathway of transferring soil PAHs to humans. To test this hypothesis
  - an in-vitro steady fluid experiment to evaluate the potential for transfer of PAHs from soil to blood through skin, and
  - a fluorescent microscopy study to determine the penetration depths of PAHs in skin.
- soil matrix and aging of PAHs in soil restricted transfer of soil PAHs from soil to humans via skin.



SC --Stratum corneum (lipids and proteins) } Act as barriers
EP --Epidermis (Several cell layes) }
D --Dermis (Live, blood vesicles and nerves)

Summary

- The pathway from contaminated soil to plant to human is insignificant for most food crops- with exception of root crops
- Best management practices focusing on reducing direct exposure to contaminated soils should be a priority as it would be the main exposure pathway of the contaminants in garden soils to humans
- Compost or other suitable soil amendment additions help reducing contaminant concentration in food crops and also, bioaccessible Pb and As to humans
- Concentration of PAHs was less in biosolids-amended soils, and this effect was more prominent for two- to three-ring PAHs than four- to six-ring PAHs
- Bioaccessibility of Pb, As and PAHs in tested urban soils were low

Acknowledgments

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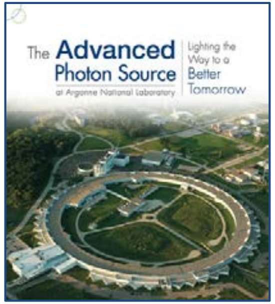
Seattle Department of Neighborhoods

United States Environmental Protection Agency



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